2011 DOE Hydrogen Program Review

Hydrogen Delivery Infrastructure Analysis

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Argonne NATIONAL LABORATORY

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Overview

Timeline

- Start: FY 2007
- End: Continuous

Budget

- 100% DOE funding
- FY10: $200 k
- FY11: $350 k

Barriers/Challenges

- Lack of analysis of H2/carrier infrastructure options and tradeoffs
- Cost and efficiency of delivery components
- Lack of appropriate models and tools/stove-piped analytical capability

Partners

- Argonne National Lab
- Pacific Northwest National Lab
- National Renewable Energy Lab

Relevance

- ❑ Provide platform for comparing alternative component, subsystem and system options to reduce cost of hydrogen delivery
  - ✓ Expand Hydrogen Delivery Scenario Analysis Model (HDSAM) to include new technology options (advanced station compression and storage, composite tube-trailers, FRP pipes, magnetic liquefaction)
  - ✓ Update capital investment for delivery components (current vs. future)
  - ✓ Update cost and price indices to be consistent across all H2A models suite
  - ✓ Investigate impact of delivery and dispensing options/strategies
- ❑ Assist in program planning
  - ✓ Investigate potential delivery pathways to achieve cost goals
  - ✓ Help with defining future funding priorities to achieve targeted performance and cost goals
- ❑ Develop new tools that build off existing DOE-sponsored tools (e.g., H2A production, Fuel Cell Power Model, GREET)
  - ✓ Collaborate with model developers and lab partners
  - ✓ Collaborate with industry for input and review

Approach

- ❑ Create **transparent, flexible, user-friendly, spreadsheet-based tool (HDSAM)** to examine new technology and options for hydrogen delivery
- ❑ Provide modeling structure to automatically link and size components into **optimized pathways** to satisfy requirements of market scenarios, and compute component and **system** costs, energy and GHG emissions
- ❑ **Collaborate** to acquire/review input assumptions, analyze delivery and dispensing options, and review results
- ❑ Provide **thorough QA**
    - ❑ Internally via partners
    - ❑ Externally, via briefings to Tech Teams, early releases to DOE researchers, industry interaction

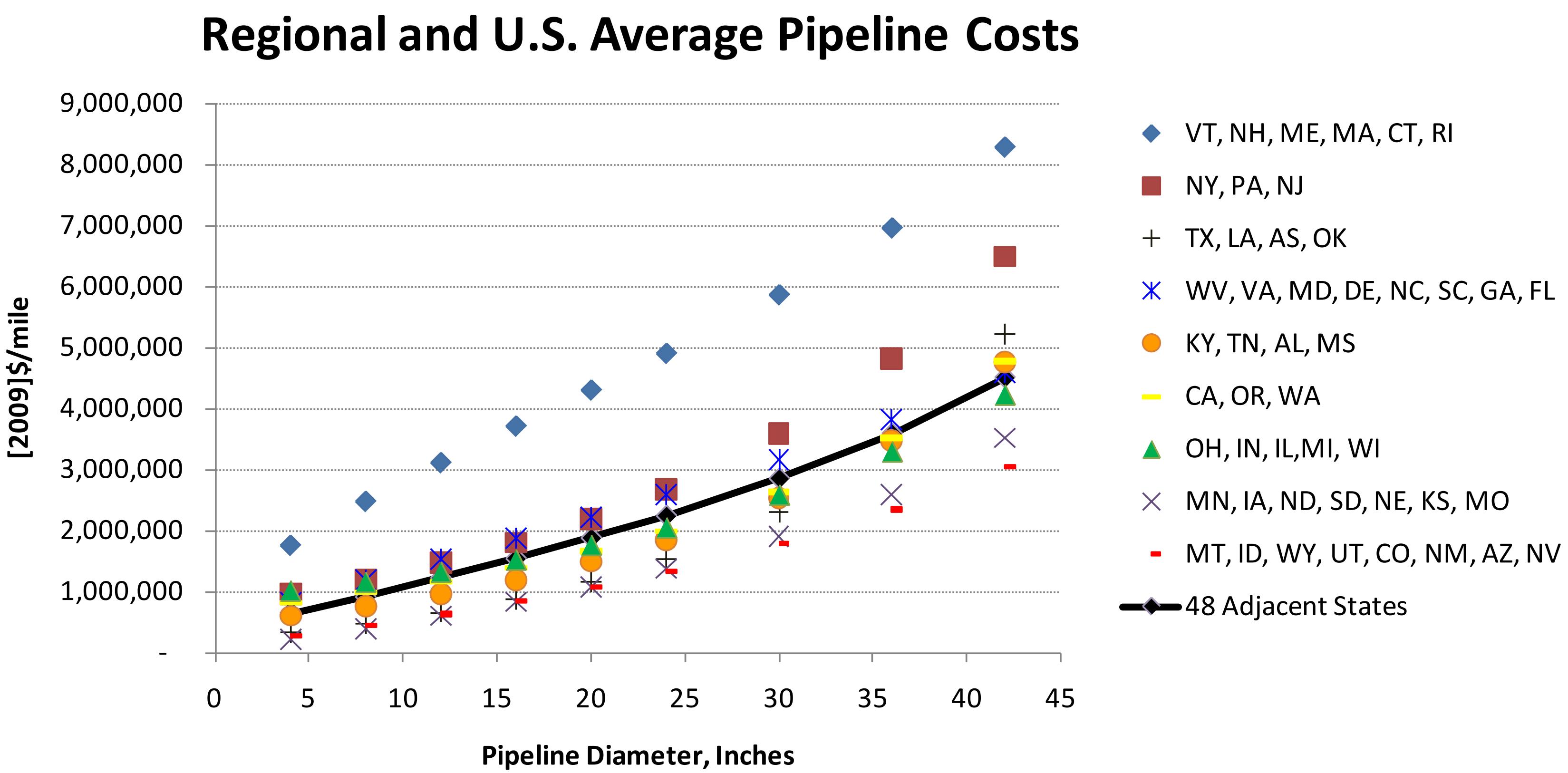
FY2011 Accomplishments

Month/Year	Milestone
December 2010	**Pipeline cost updates**
February 2011	**Cost/price index updates**
March 2011	**Refueling station and delivery cost target analysis**
June 2011	Investigate viability of geologic storage (cost and availability)
Continuous	IEA Task 28 support (November 2010 startup)
September 2011	HDSAM 2.3

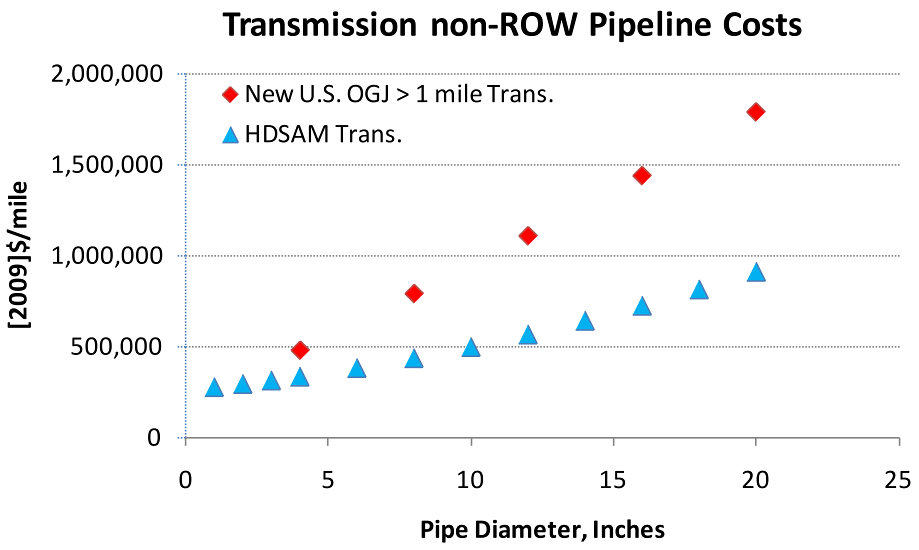
UPDATING PIPELINE COST FUNCTIONS

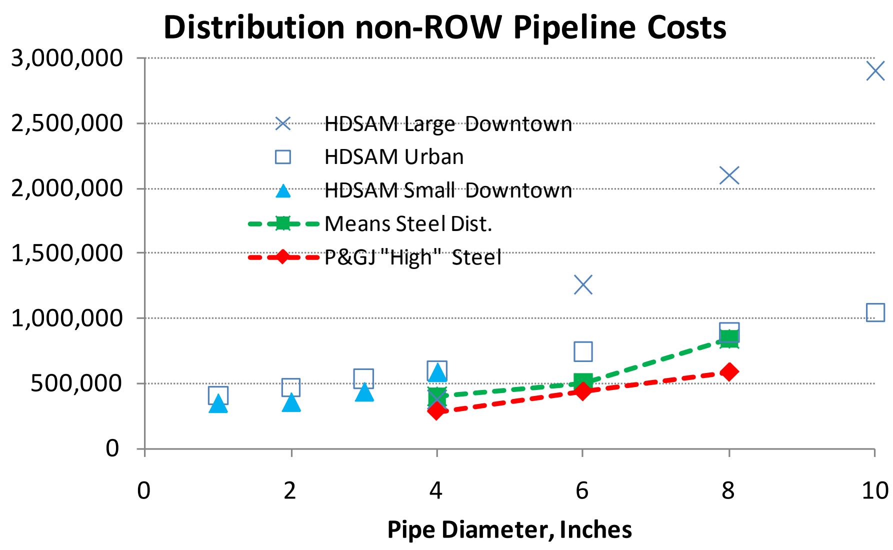
Steel Pipeline Transmission Cost

- Statistical analysis of data published by the Oil and Gas Journal for the last 30 years
- Updated equations for estimating material, labor, right-of-way, and miscellaneous costs
- Equations developed for nine U.S. regions and U.S. as a whole
- Incorporated newly developed cost equations into pipeline model of HDSAM
- Article published in the 01/03/11 edition of the Oil and Gas Journal

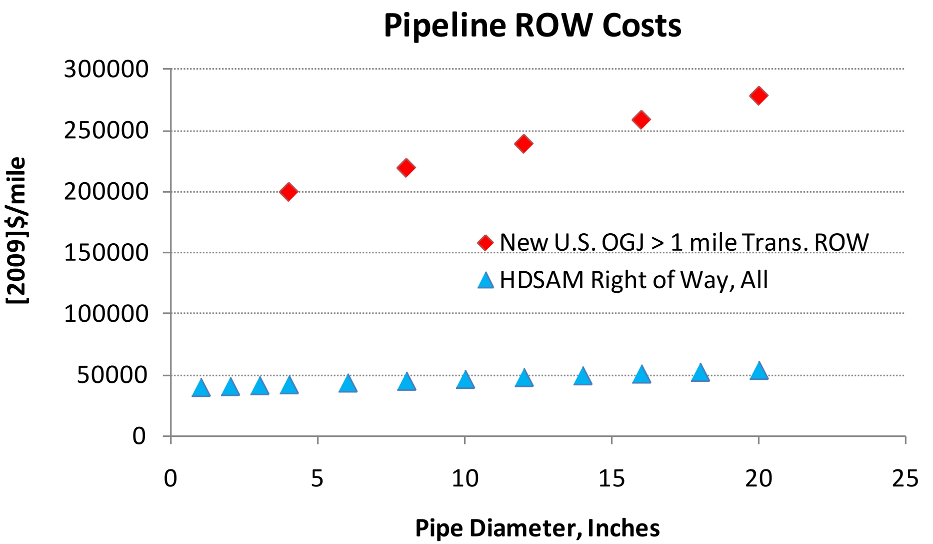


Pipeline Cost Function Updates





Non-ROW costs have increased by up to a factor of two



ROW costs have increased the most on a percentage basis

Fiber-Reinforced Polymer (FRP) Piping

- Flexible, hence spoolable, high-pressure piping. Maximum spoolable diameter about 6 inches
- Material cost greater than steel, but labor cost less and labor dominates steel piping installed costs
- Used in natural gas gathering; being tested at ORNL for use with hydrogen
- Wide-ranging estimates of relative cost in literature; article co-authored by industrial customer (EnCana) most compelling
- Ecana: 20% increase in material; 25% less labor; 15% overall reduction
- Long-run: competition and installation learning should result in improved cost advantage relative to steel

COST/PRICE INDEX UPDATES

Cost and Price Indices

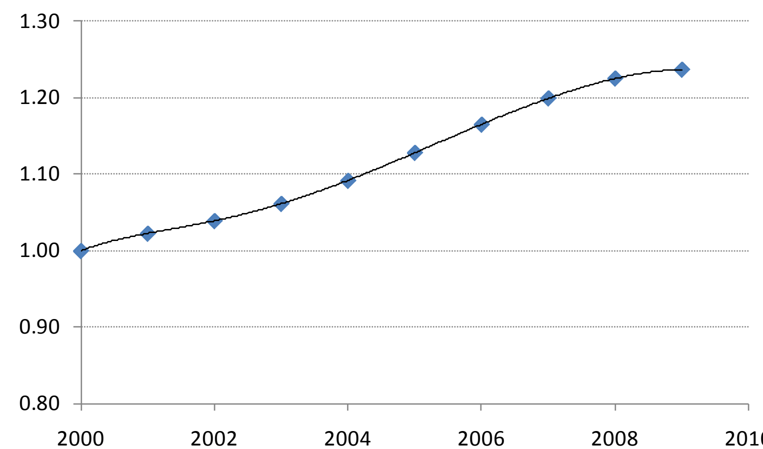
Chemical Engineering Plant Cost Index

	2005	2006	2007	2008	2009	2010
Overall Index	1.0	1.067	1.122	1.229	1.115	1.182
Equipment	1.0	1.081	1.148	1.282	1.132	1.221
Heat Exchanges and Tanks	1.0	1.066	1.152	1.338	1.086	1.206
Process Machinery	1.0	1.058	1.151	1.238	1.152	1.210
Pipe, valves and fittings	1.0	1.135	1.176	1.327	1.220	1.315
Process Instruments	1.0	1.100	1.114	1.138	1.041	1.095
Pumps and Compressions	1.0	1.044	1.105	1.158	1.192	1.197
Electrical equipment	1.0	1.083	1.157	1.232	1.240	1.295
Structural supports	1.0	1.069	1.133	1.280	1.076	1.177
Construction Labor	1.0	1.012	1.031	1.053	1.071	1.072
Buildings	1.0	1.053	1.071	1.139	1.105	1.141
Engineering Supervision	1.0	1.012	1.029	1.018	1.000	0.977

Bureau of Labor Statistics

Year	Labor Cost Index
2000	0.87
2001	0.89
2002	0.91
2003	0.94
2004	0.97
2005	1.00
2006	1.00
2007	0.99
2008	0.99
2009	1.03

AEO 2009 and GDP Implicit Deflator Price Index

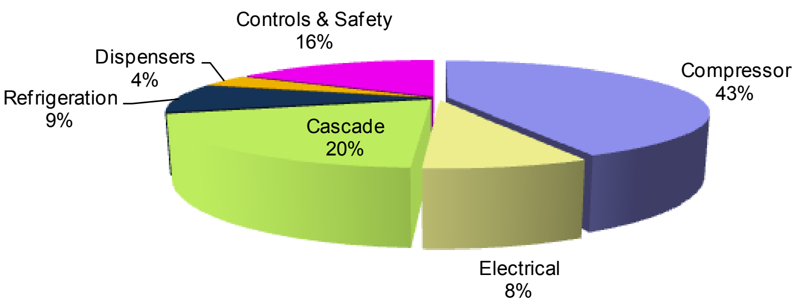


REFUELING STATION ANALYSIS

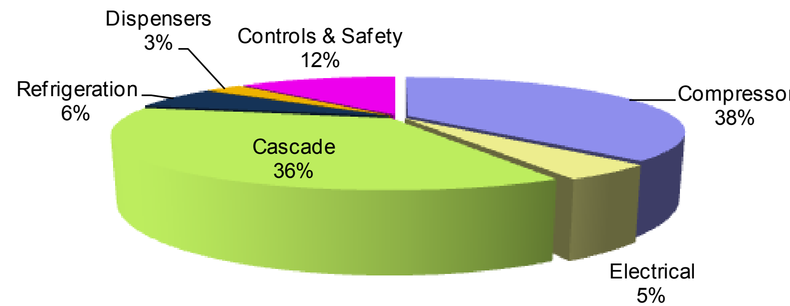
Factors Impacting Station's Capital Investment and Levelized Cost

- FCV market penetration
  - 1^{st} plant vs. n^{th} plant
  - Station size
  - Station utilization
  - Investment risk and rate of return
- FCV onboard storage option
- Station design configuration

1st Plant Versus nth Plant

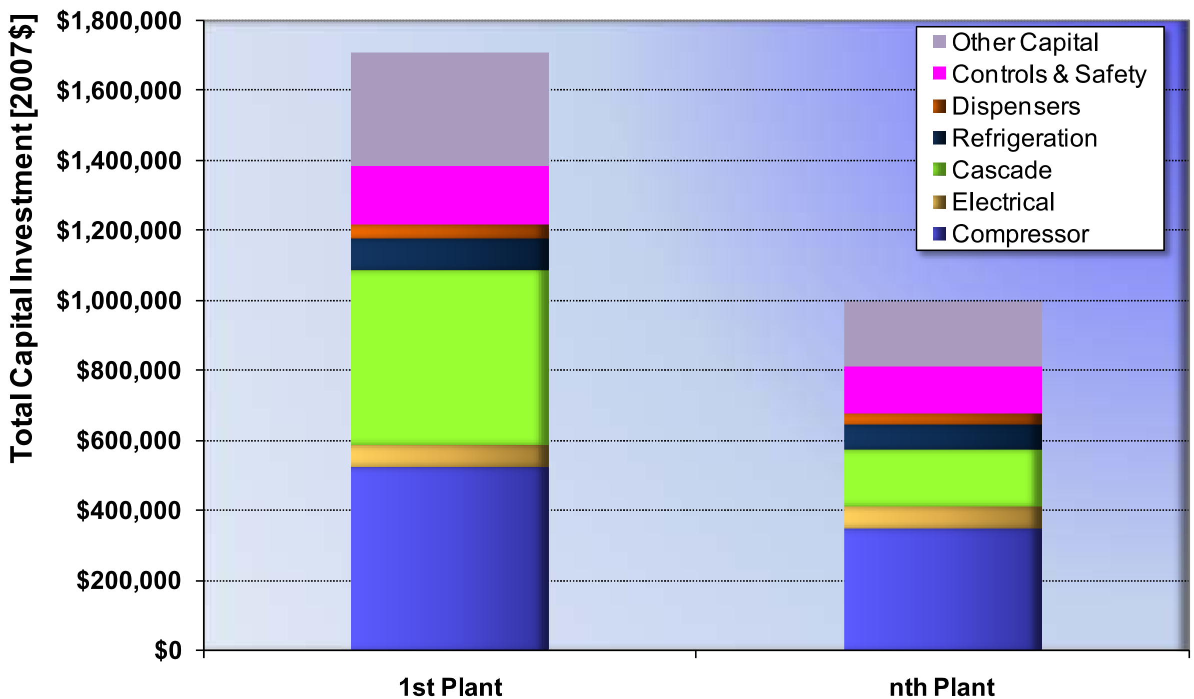


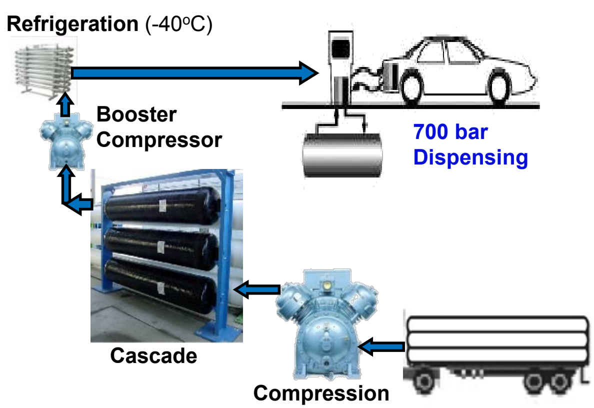
1st Plant



nth Plant

200 kg/day Station

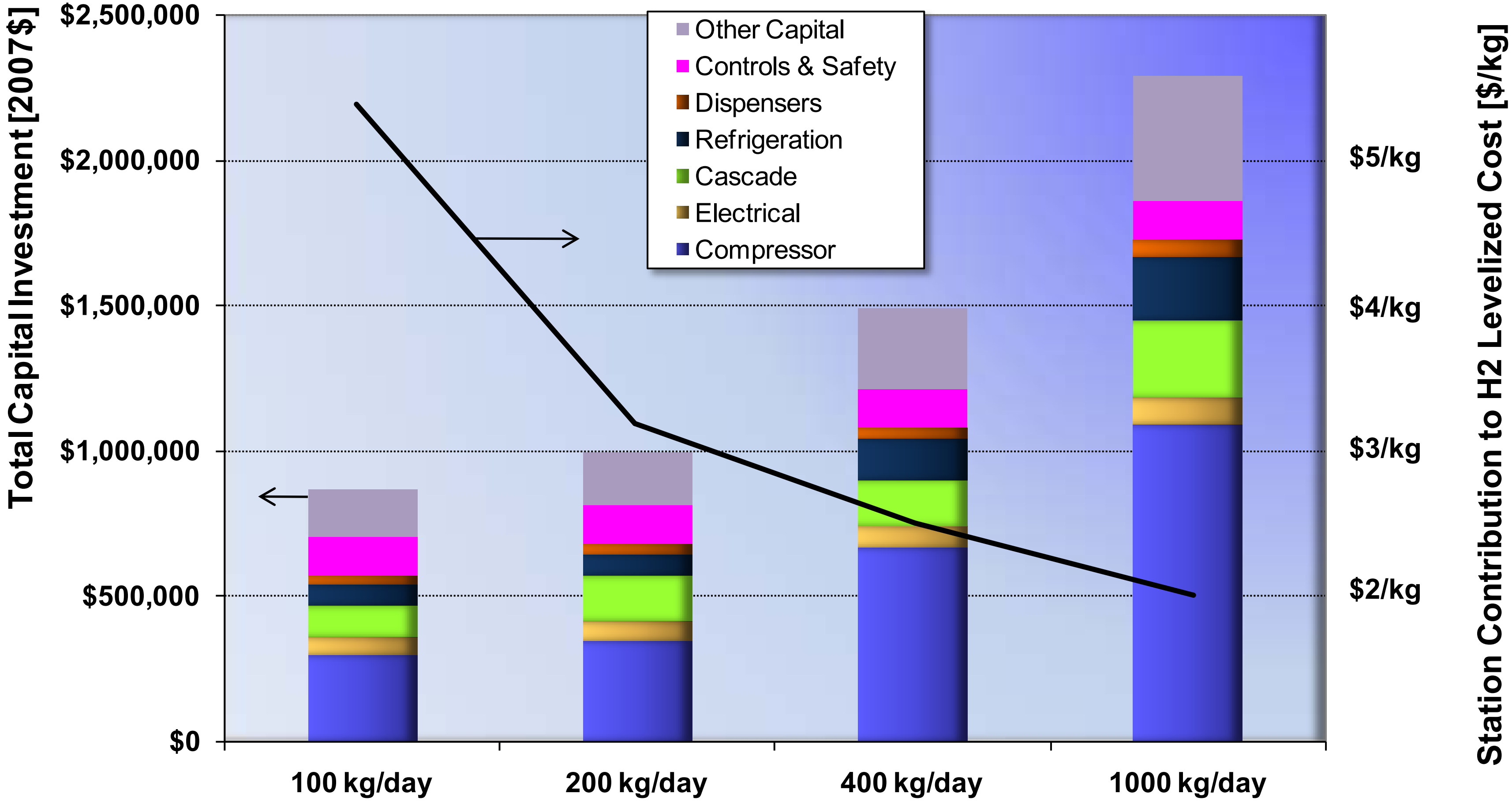




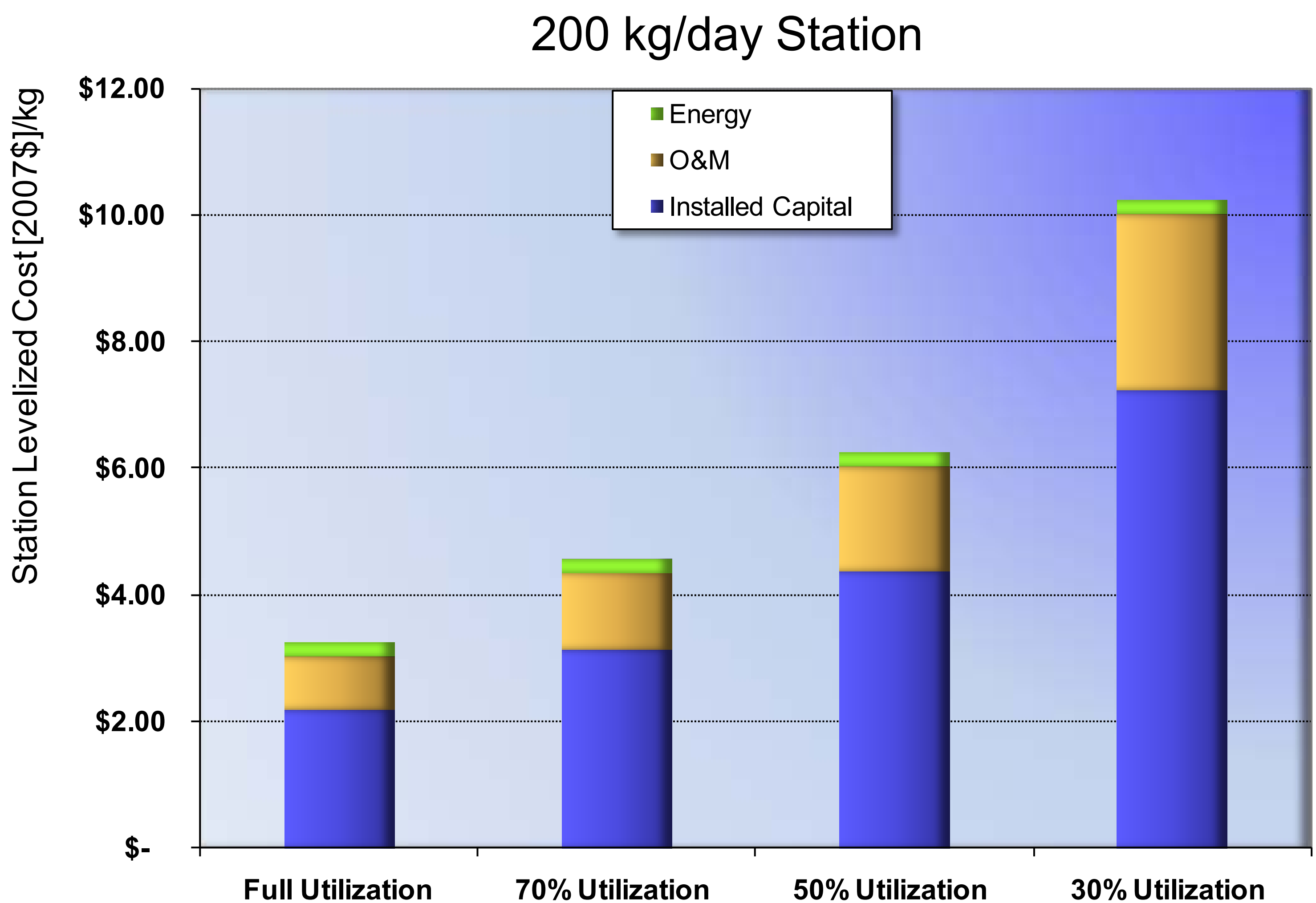
$5.10/kg

$3.25/kg ← Station contribution to levelized cost

Station Size

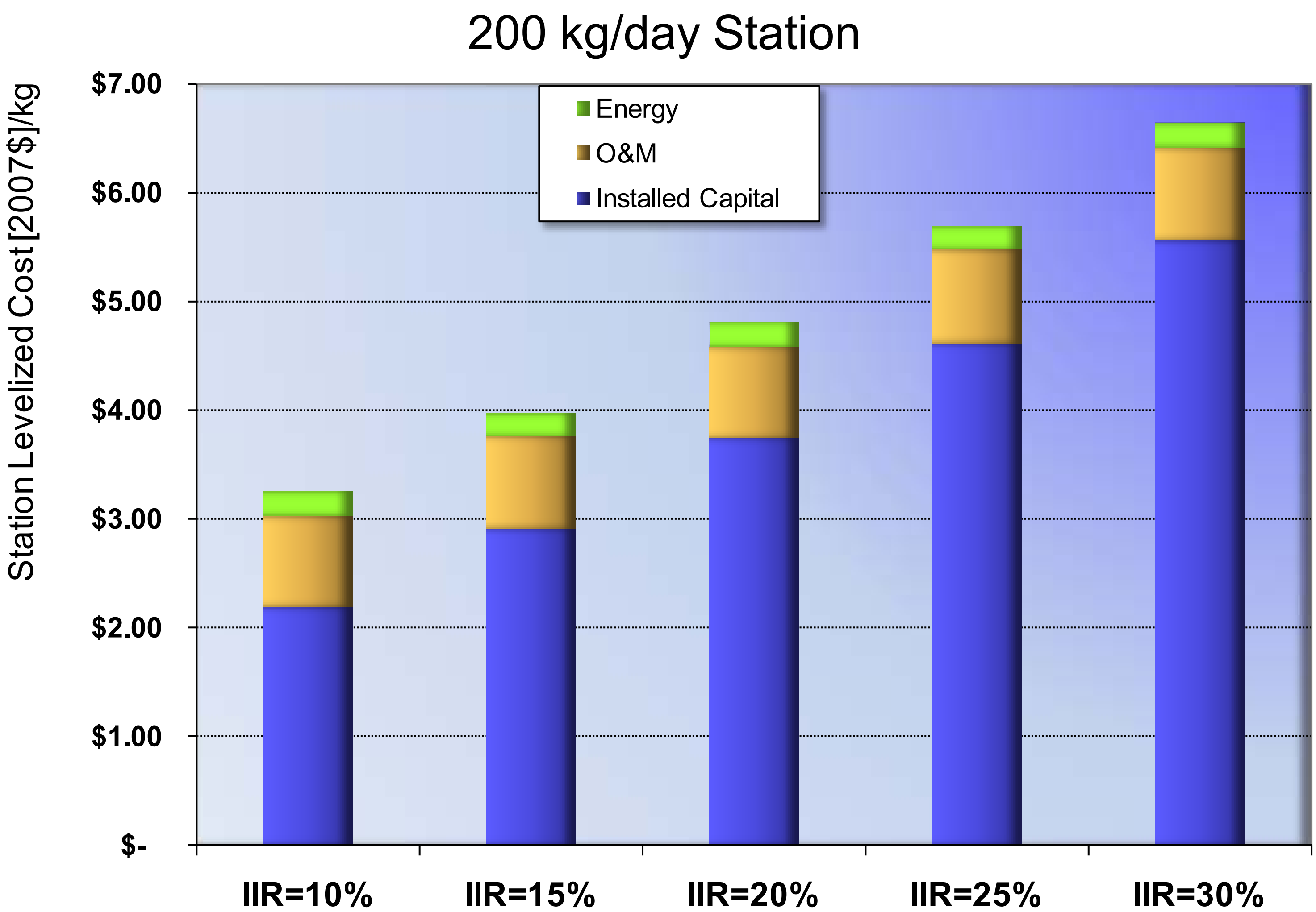


*Station Utilization**

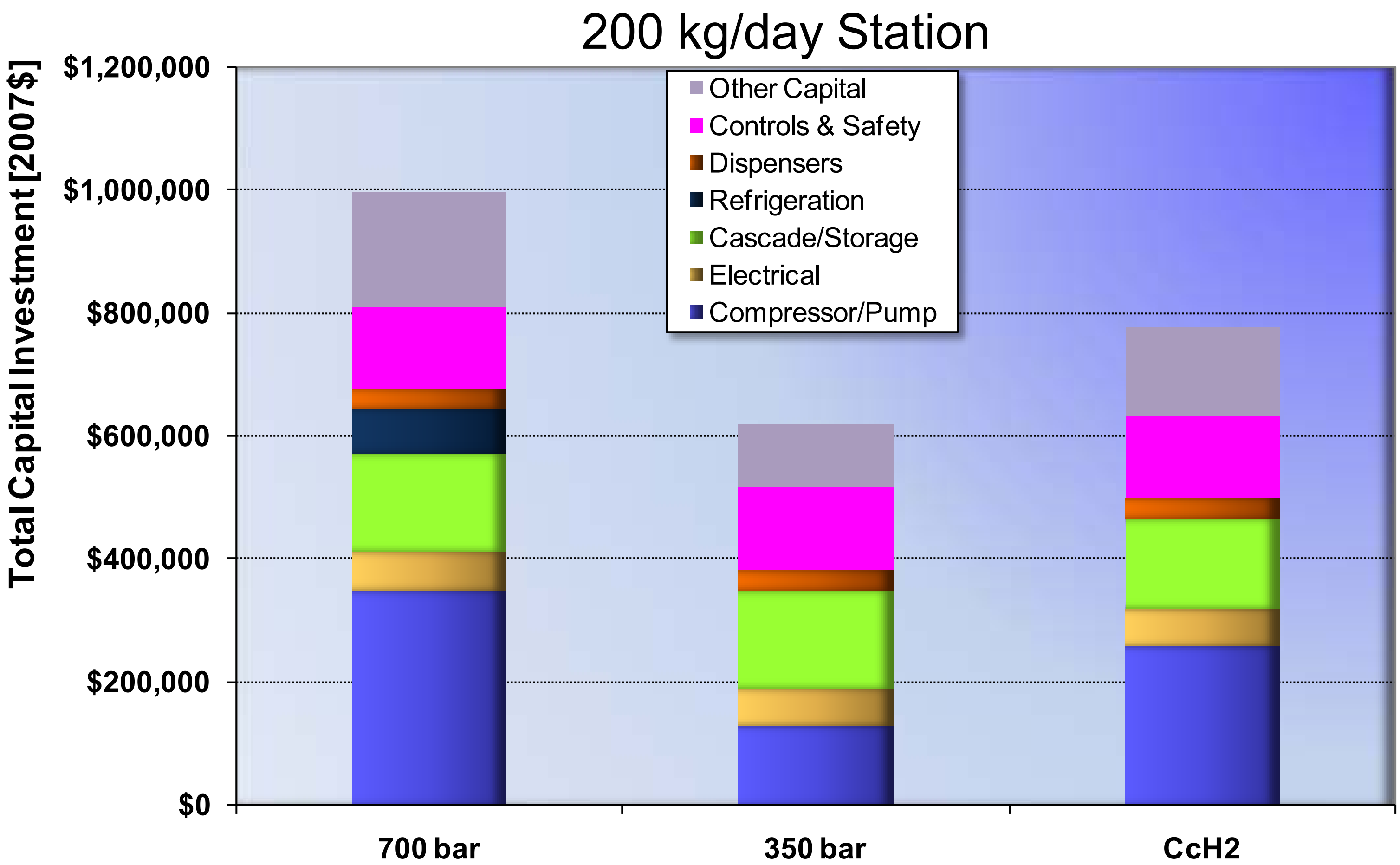


*utilization = actual daily amount dispensed / projected daily demand for the station
For example: 30% utilization of a 200 kg/day station means that the station is dispensing only 30% of 200, i.e., 60 kg/day

Investment Risk and Rate of Return



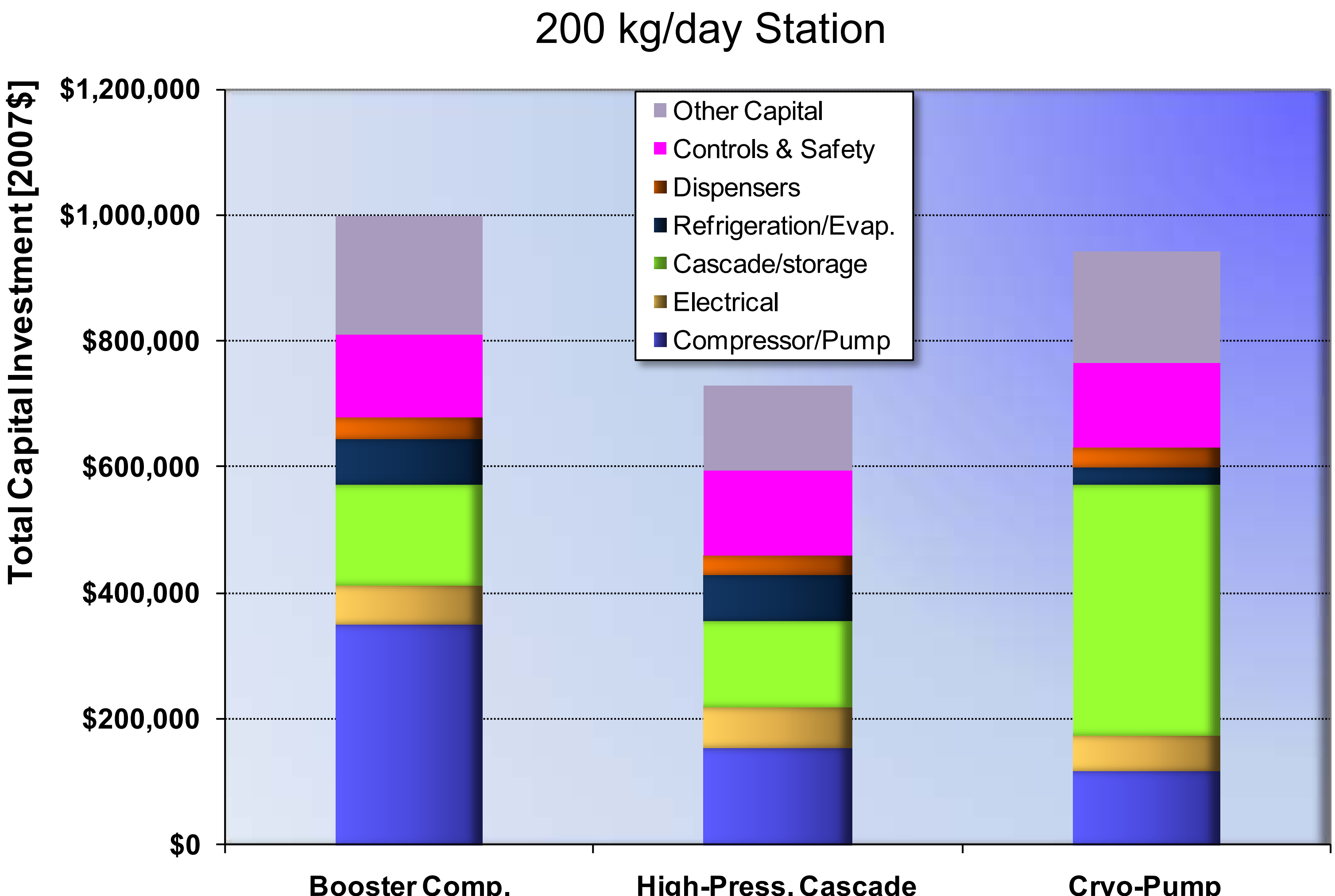
FCV Onboard Storage Option



Station contribution to levelized cost → $3.25/kg $1.85/kg $2.60/kg

Station Configuration

(700 bar dispensing via booster comp., high-press. cascade, or cryo-pump)



Station contribution to levelized cost → $3.25/kg $2.40/kg $3.00/kg

DELIVERY COST TARGET ANALYSIS

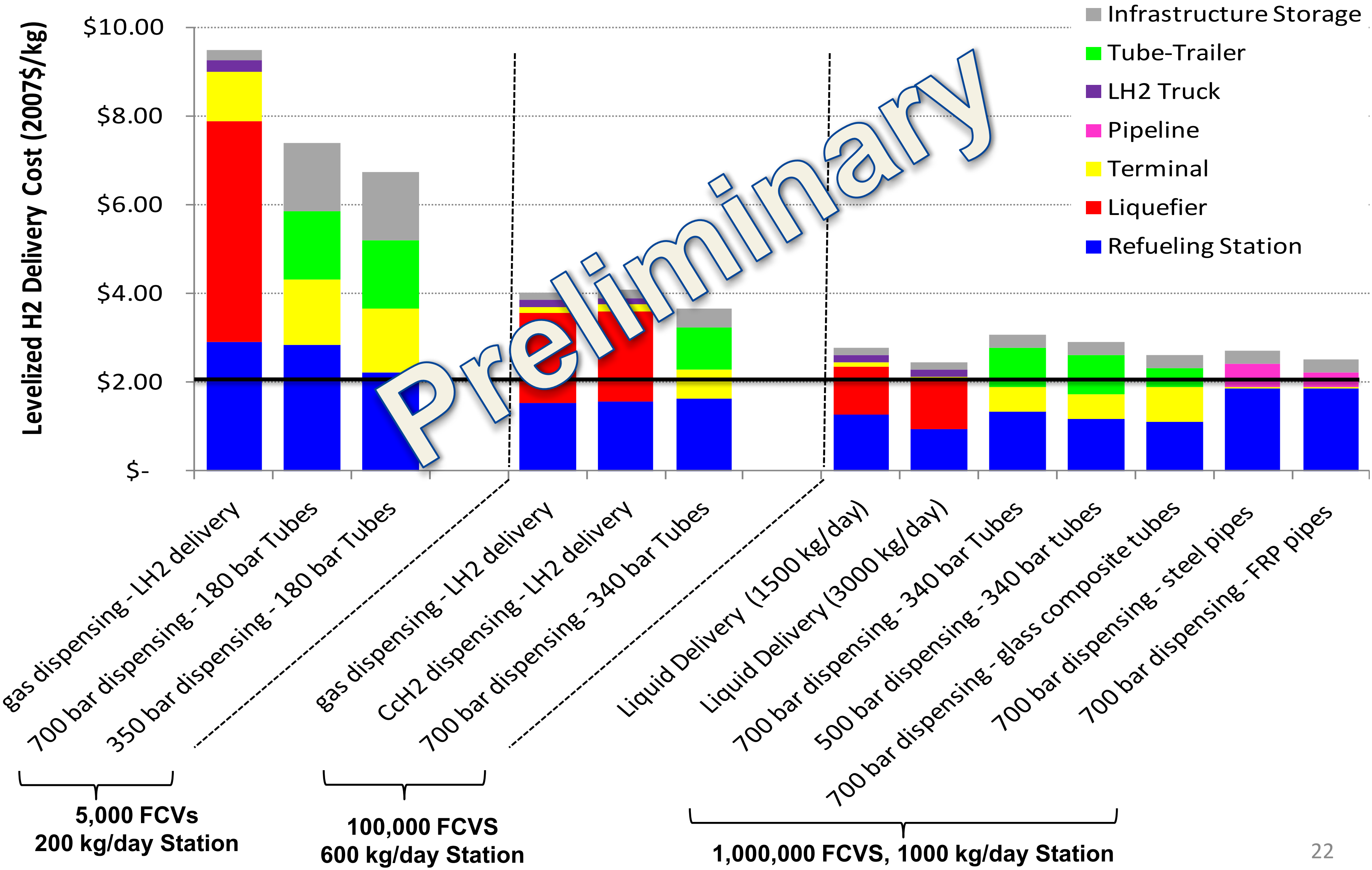
Objectives of Delivery Cost Target Analysis

- Understand the impact of delivery technology options and economies of scale on hydrogen delivery cost

- Examine the cost of various delivery options with respect to a delivery cost target of \$2/kg

- Identify components with the greatest impact on delivery cost for future research and development

Levelized Hydrogen Delivery Cost Reduction Path



Future Work

Month/Year	Milestone
June 2011	Complete delivery cost target analysis
June 2011	Investigate viability of geologic storage (cost and availability)
December 2011	Post HDSAM 2.3
September 2012	Examine technology and pathway options to reduce refueling station cost

Project Summary

- **Relevance:** Provide platform to evaluate hydrogen delivery (in $, energy and GHG emissions), estimate impact of alternative conditioning, distribution and storage options; incorporate advanced options as data become available; assist Hydrogen Program in target setting.
- **Approach:** Develop models of hydrogen delivery components and systems to quantify costs and analyze alternative technologies and operating strategies.
- **Collaborations**: Active partnership among ANL, PNNL and NREL, plus regular interaction with Fuel Pathways and Delivery Tech Teams, DOE researchers and industry analysts.
- **Technical accomplishments and progress:**
  - Pipeline cost updates and alternative technologies evaluated
  - Delivery pathway options for cost target analysis begun
  - Fuel station cost re-evaluated
  - Analysis of geologic storage cost and availability begun
- **Future Research**: Expand models to include new technology options for refueling stations (advanced compression, storage), revise/update data, and respond to Tech Team recommendations.

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Project PD14